Section

APPENDIX B

The following examples illustrate the use of life cycle analysis techniques for highway projects based on UDOT data.

Example 1

The Utah Department of Transportation is attempting to analyze the most cost effective alternative for construction of a four lane Interstate Highway. The two alternatives to be evaluated are the construction of a Portland Cement Concrete Pavement compared with the construction of an Asphaltic Concrete Pavement. The following costs per mile of construction are known for each alternative:

Portland Cement Concrete Pavement (Alternative 1)

Initial Construction Cost	$1,200,000
Joint Sealing (year 10 & 20)	$84,000
Routine Annual Maintenance	$1,800
Salvage	($140,000)

Asphaltic Concrete Pavement (Alternative 2)

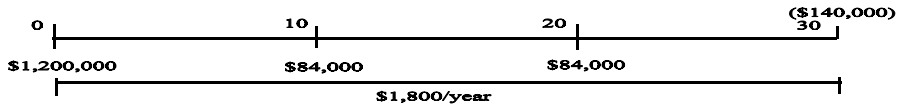
Initial Construction Cost	$900,000
Stage II Construction (year 10)	$350,000
Recycle Pavement (year 20)	$290,000
Rout1ine Annual Maintenance	$1,000
Salvage	($280,000)

The estimated life of each alternative is 30 years. Use a 4% discount rate to find the best alternative.

Solution:

The alternative may be evaluated using either the Present Worth Method or the Annual Worth Method. Both solutions are shown. The first step is to construct a time line using the above costs. Then plug the appropriate values into the associated formula.

Alternative 1



Present Worth Method

P = $1,200,000 + $84,000 (P/F, 4%, 10) + $84,000 (P/F, 4%, 20)
+ $1,800 (P/A, 4%, 30) - $140,000 (P/F, 4%, 30)

= 1,200,000 + 84,000 (0.6756) + 84,000 (0.4564) + 1,800 (17.2920) - 140,000 (0.3083)

= $1,283,045 } ANSWER

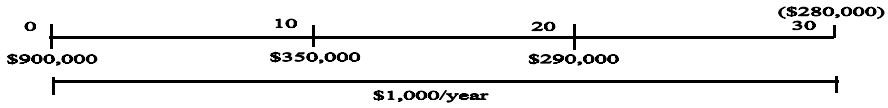
Annual Worth Method

A = $1,200,000 (A/P, 4%, 30) + $84,000 (P/F, 4%, 10) (A/P, 4%,30)
+ $84,000 (P/F, 4%, 20) (A/P, 4%, 30) + $1,800 - $140, 000 (A/F, 4%, 30)

= 1,200,000 (0.0578) + 84,000 (0.6756) (0.0578) + 84,000 (0.4564) (0.0578)
+ 1,800 - 140,000 (0.0178)

= $74,199 } ANSWER

Alternative 2



Present Worth Method

P = $900,000 + $350,000 (P/F, 4%, 10) + $290,000 (P/F, 4%, 20)
+ $1,000 (P/A, 4%, 30) - $280,000 (P/F, 4%, 30)

= 900,000 + 350,000 (0.6756) + 290,000 (0.4564) + 1,000 (17.2920) - 280,000 (0.3083)

= $1,199,762 } ANSWER

Annual Worth Method

A = $900,000 (A/P, 4%, 30) + $350,000 (P/F, 4%, 10) (A/P, 4%,30)
+ $290,000 (P/F, 4%, 20) (A/P, 4%, 30) + $1,000 - $280, 000 (A/F, 4%, 30)

= 900,000 (0.0578) + 350,000 (0.6756) (0.0578) + 290,000 (0.4564) (0.0578)
+ 1,000 - 280,000 (0.0178)

= $69,382 } ANSWER

Comparison of Alternatives

	Alternative 1	Alternative 2
Present Worth	$1,283,045	$1,199,762
Annual Worth	$74,199	$69,382

Conclusion

As can be seen in the comparison above, Alternative 2 is the least expensive alternative. This example also illustrates that the use of either the annual worth or present worth method leads to the same conclusion.

Sensitivity Analysis

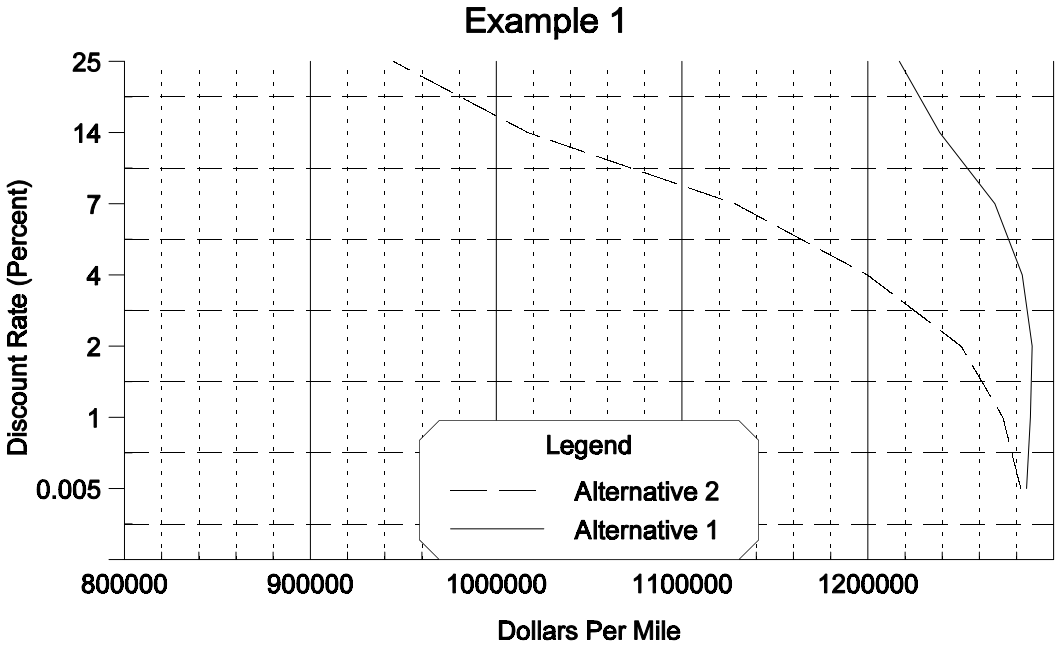
Cost Benefit Variable

Discount Rate
Analysis Period
Maintenance Cost
User Cost

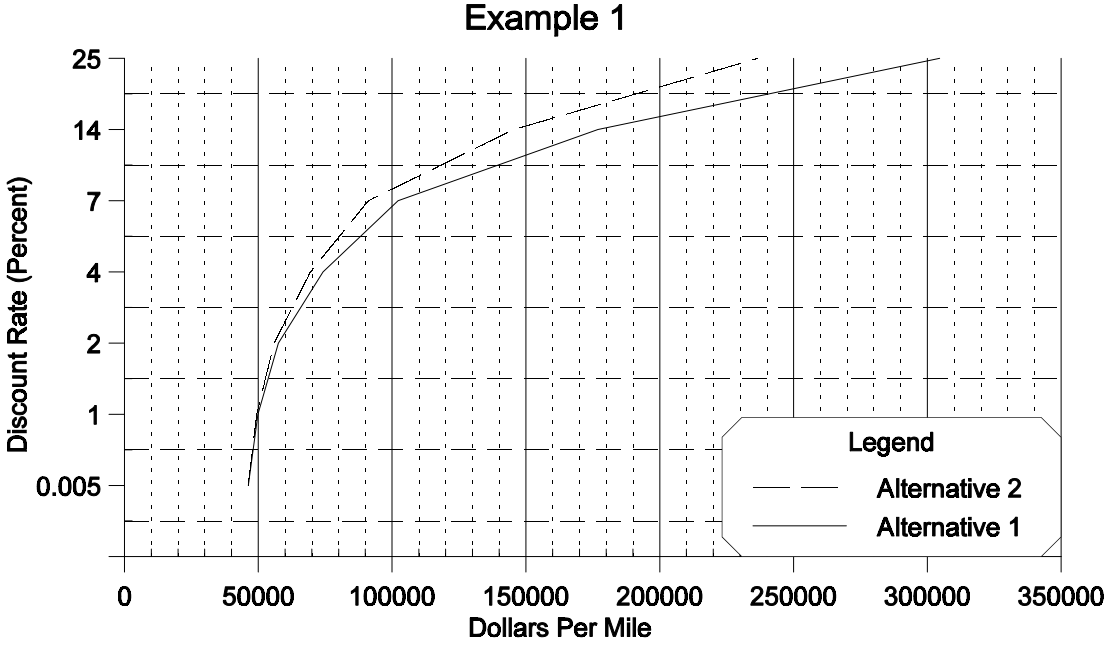
Present Worth Method Example 1		
Discount Rate	**Alternative 1**	**Alternative 2**
0.5%	$1,285,424	$1,282,146
1%	$1,287,471	$1,272,588
2%	$1,288,463	$1,250,100
4%	$1,283,045	$1,199,762
7%	$1,268,353	$1,128,490
14%	$1,238,627	$1,017,018
25%	$1,217,006	$944,573

Annual Worth Method Example 1		
Discount Rate	**Alternative 1**	**Alternative 2**
0.5%	$46,248	$46,130
1%	$49,887	$49,310
2%	$57,530	$55,817
4%	$74,199	$69,382
7%	$102,212	$90,941
14%	$176,880	$145,233
25%	$304,629	$236,436

COMPARISON - PRESENT WORTH ALTERNATIVE



COMPARISON - ANNUAL WORTH ALTERNATIVES



Example 2

A Value Engineering Study has identified two alternative solutions for rehabilitating a principal arterial highway. Given the following information about each alternative, select the most cost effective. The following costs per mile of construction are known for each alternative:

Alternative 1

Provide a bituminous surface treatment (BST) for the next 12 years, followed by reconstruction with asphaltic concrete pavement.

BST Applications (6 year cycles)	$97,000
Reconstruction (year 12)	$483,000
Annual Maintenance (years 1 - 12)	16,000
Annual Maintenance (years 13-30)	4,000
Resurfacing (year 24)	$266,000
Salvage	($132,000)

Alternative 2

Provide reconstruction now with rehabilitation in 12 years.

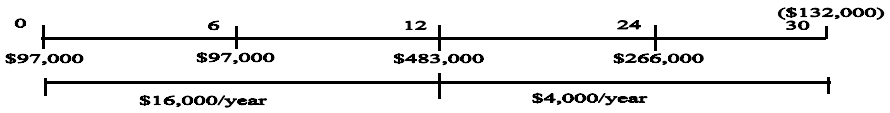
Reconstruction	$483,000
Rehabilitation (year 12)	$306,000
Annual Maintenance (year 1 -12)	$4,000
Annual Maintenance (year 13 - 30)	$1,600
Resurface (year 24)	$266,000
Salvage	$(132,000)

The estimated life of each alternative is 30 years. Use a 4% discount rate to find the best alternative.

Solution:

The alternative may be evaluated using either the Present Worth Method or the Annual Worth Method. Both solutions are shown. The first step is to construct a time line using the above costs. Then plug the appropriate values into the associated formula.

Alternative 1



Present Worth Method

P = $97,000 + $97,000 (P/F, 4%, 6) + $483,000 (P/F, 4%, 12) + $266,000 (P/F, 4%, 24) + $16,000 (P/A, 4%, 12) + 4,000 (P/A, 4%, 18) (P/F, 4%, 12) - $132,000 (P/F, 4%, 30)

= 97,000 + 97,000 (0.7903) + 483,000 (0.6246) + 266,000 (0.3901) + 16,000 (9.3851) + 4,000 (12.6593) (0.6246) - 132,000 (0.3083)

= $720,204 } ANSWER

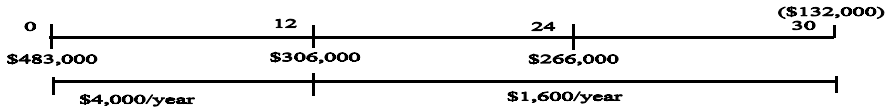
Annual Worth Method

A = $97,000 (A/P, 4%, 30) + $97,000 (P/F, 4%, 6) (A/P, 4%,30) + $483,000 (P/F, 4%, 12) (A/P, 4%, 30) + $266,000 (P/F, 4%, 24) (A/P, 4%, 30) + 16,000 (P/A, 4%, 12) (A/P, 4% 30) + 4,000 (P/A, 4%, 18) (P/F, 4%, 12) (A/P, 4% 30) - $132, 000 (A/F, 4%, 30)

= 97,000 (0.0578) + 97,000 (0.7903) (0.0578) + 483,000 (0.6246) (0.0578) + 266,000 (0.3901) (0.0578) + 16,000 (9.3851) (0.0578) + 4,000 (12.6593) (0.6246) (0.0578) - 132,000 (0.0178)

= $41,650 } ANSWER

Alternative 2



Present Worth Method

P = $483,000 + $306,000 (P/F, 4%, 12) + $266,000 (P/F, 4%, 24)
+ 4,000 (P/A, 4%, 12) + $16000 (P/A, 4%, 18) (P/F, 4%, 12)
- $132,000 (P/F, 4%, 30)

= 483,000 + 306,000 (0.6246) + 266,000 (0.3901) + 4,000 (9.3851)
+ 1,600 (12.6593) (0.6246) - 132,000 (0.3083)

= $787,392 } ANSWER

Annual Worth Method

A = $483,000 (A/P, 4%, 30) + $306,000 (P/F, 4%, 12) (A/P, 4%,30)
+ $266,000 (P/F, 4%, 24) (A/P, 4%, 30) + $4,000 (P/A, 4% 12) (A/P, 4%, 30)
+ 1,600 (P/A, 4%, 18) (P/F, 4%, 12) (A/P, 4%, 30) - $132, 000 (A/F, 4%, 30)

= 483,000 (0.0578) + 306,000 (0.6246) (0.0578) + 266,000 (0.3901) (0.0578)
+ 4,000 (9.3851) (0.0578) + 1,600 (12.6593) (0.6246) (0.0578) - 132,000 (0.0178)

= $45,535 } ANSWER

Comparison of Alternatives

	Alternative 1	Alternative 2
Present Worth	$720,204	$787,392
Annual Worth	$41,650	$45,535

Conclusion

As can be seen in the comparison above, Alternative 1 is the least expensive alternative. This example also illustrates that the use of either the annual worth or present worth method leads to the same conclusion.

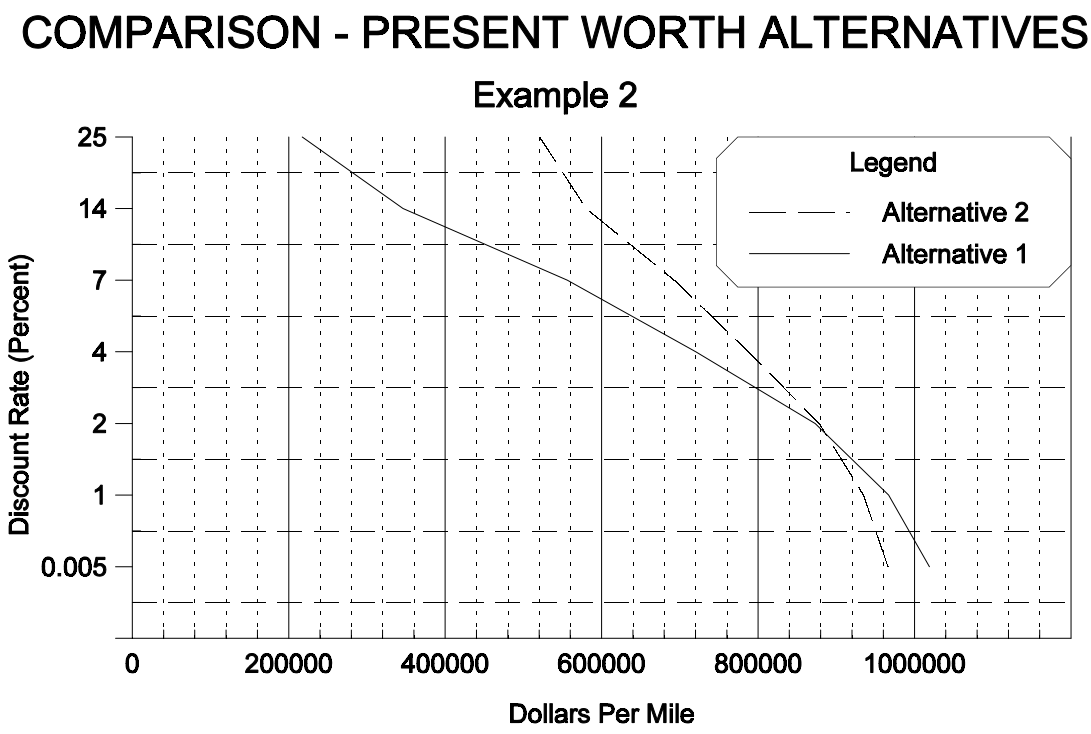
Sensitivity Analysis

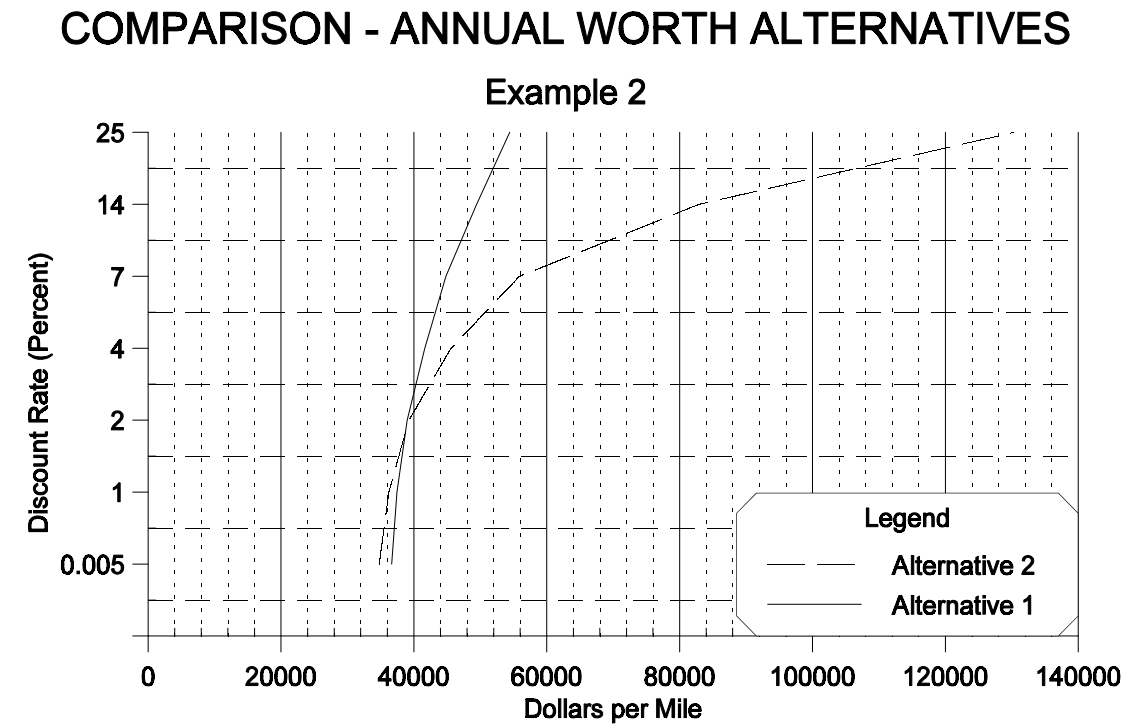
Cost Benefit Variable

Discount Rate
Analysis Period
Maintenance Cost
User Cost

Present Worth Method Example 2		
Discount Rate	**Alternative 1**	**Alternative 2**
0.5%	$1,019,019	$965,914
1%	$966,867	$934,423
2%	$872,970	$877,999
4%	$720,204	$787,392
7%	$556,142	$692,885
14%	$346,246	$580,171
25%	$217,394	$520,453

Annual Worth Method Example 2		
Discount Rate	**Alternative 1**	**Alternative 2**
0.5%	$36,663	$34,753
1%	$37,464	$36,207
2%	$38,978	$39,203
4%	$41,650	$45,535
7%	$44,817	$55,837
14%	$49,445	$82,850
25%	$54,416	$130,275


COMPARISON - PRESENT WORTH ALTERNATIVES
Example 2
Discount Rate (Percent)
25
14
7
4
2
1
0.005
0
200000
400000
600000
800000
1000000
Dollars Per Mile
Legend
Alternative 2
Alternative 1


COMPARISON - ANNUAL WORTH ALTERNATIVES
Example 2
Discount Rate (Percent)
25
14
7
4
2
1
0.005
0
20000
40000
60000
80000
100000
120000
140000
Dollars per Mile
Legend
Alternative 2
Alternative 1